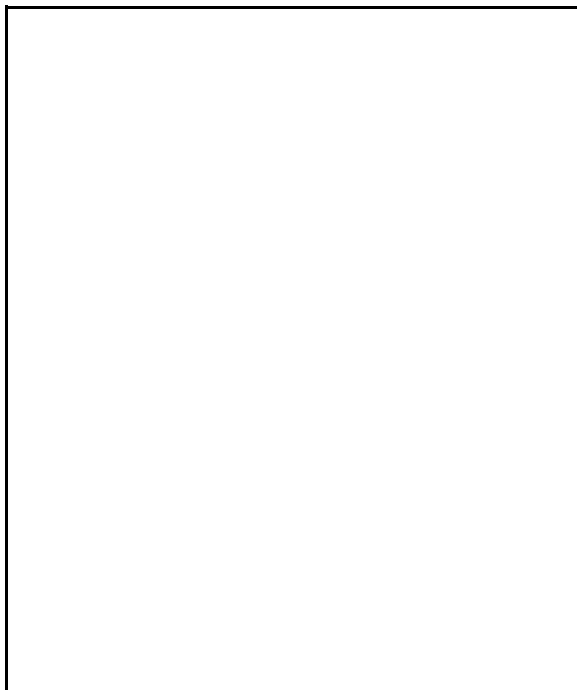


## Office of Industrial Technologies

*The EE Office of Industrial Technologies (OIT) supports the energy needs of the industrial sector of the economy. The mission of OIT is to develop and deploy—through cost-shared partnerships with industry, government, and nongovernment organizations—advanced energy efficiency, improved productivity, renewable energy, and pollution prevention technologies.*

### **Industries of the Future**

Industries of the Future is a process in which industry participants—facilitated by OIT—create a vision that reflects the diverse technological, economic, and environmental drivers that are shaping the future of their industry. The vision is developed by industry, for industry. It provides a framework for shaping major advancements in technologies according to their potential for improving industrial efficiency, energy and materials use, and environmental protection. The development of its vision facilitates integrated planning and implementation by all participants in industry and focuses research, development, and demonstration on technologies that are responsive to the unique challenges each industry faces.



NREL's Thermochemical Users Facility, housed in the Field Test Laboratory building, is a configuration of reactors that convert renewable feedstocks into electricity, high-value chemicals and transportation fuels, processing as much as a half-ton of biomass or wastes a day. (Photo - Warren Gretz, NREL)

Because certain industries possess the greatest opportunities for improved energy efficiency, OIT's Industries of the Future initiative concentrates on the seven most energy-intensive industries: aluminum, chemicals, forest products, glass, metal casting, petroleum refining, and steel. Agriculture is another area recently added. OIT supports technologies that target energy efficiency, pollution prevention, and waste reduction, enhancing not only the industry's energy efficiency but also its materials efficiency and environmental characteristics.

U.S. industry consumes about 23 quadrillion Btu (quads) of energy each year. Industry's appetite for energy results in an annual expense of about \$100 billion/year. DOE forecasts that despite efficiency improvements, total industrial energy use will grow by 22% by the year 2010.

Even more important is the cost of pollution control and compliance. These industries generate huge quantities of waste and pollution as they convert raw materials into ingredients useful for

manufacturing. Such conversion from raw materials is inherently more waste and pollution intensive than conversion from waste products. The seven industries account for 95% of the manufacturing wastes, and incur twice the amount in pollution control costs than do other manufacturing industries.

NREL has developed a world reputation in the understanding of biomass and its conversion to fuels, electricity, and industrial chemicals and materials. NREL's vision includes developing the biomass source, in the long term, as an alternative to petroleum in a concept analogous to a biomass refinery. In a biomass refinery, a large number of products are obtained from biomass, including bio-derived oil, electricity, chemicals, and materials. As industrial and municipal wastes became a target of emphasis in the 1980s, NREL included the waste materials from industrial processes and post-consumer use as a possible source of raw materials for its processes in addition to biomass. In fact,

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**NREL has developed a world reputation in the understanding of biomass and its conversion to fuels, electricity, and industrial chemicals and materials.**

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during the 1990s, industry has come to realize that reducing industrial waste reflects positively on their profits and public image in addition to energy savings, and their own initiatives in reducing wastes may ease public pressures and legislative mandates.

Consistent with the initiatives of the DOE Office of Industrial Technologies and with NREL's core capabilities and scientific and technical skills, NREL has chosen to focus its attention on forest products, agriculture, chemicals, and petroleum refining. Included in the chemical industry vision is the conversion of alternative biomass and agricultural feedstocks to chemicals. Agriculture may become an independent area of focus for DOE and NREL in the future. NREL has capabilities in metal casting, specialty glass, and aluminum.

NREL has provided leadership in the formation of the Laboratory Coordinating Council and continues to guide its activities by participating in the Executive committee of the Council. This council comprises 17 DOE laboratories and manufacturing facilities, and helps the formation of virtual centers of excellence in these areas of the Industries of the Future program. NREL leadership has established the Council's credibility with industry and DOE; NREL currently chairs the Council.

## Chemicals Industry

The chemical industry sector has published and is following an industry vision outlined in its document, *Chemical Vision 2020*. This effort was created in its final form by industry in late 1996 and represents input from five industry associations and their memberships.



NREL supports the chemical industry's needs through research on recycled and recyclable materials. One area of research uses photosynthetic bacteria to help bring down the cost of biodegradable plastics. (Photo - Warren Gretz, NREL)

It outlines four technology areas that will assist this industry in maintaining and developing its competitiveness into the second decade of the next century: new science and engineering technology, information systems, supply chain management, and manufacturing operations. The technology roadmaps will be developed in 1997 and will form the basis for continuing NREL involvement in addressing industry's research and technology needs.

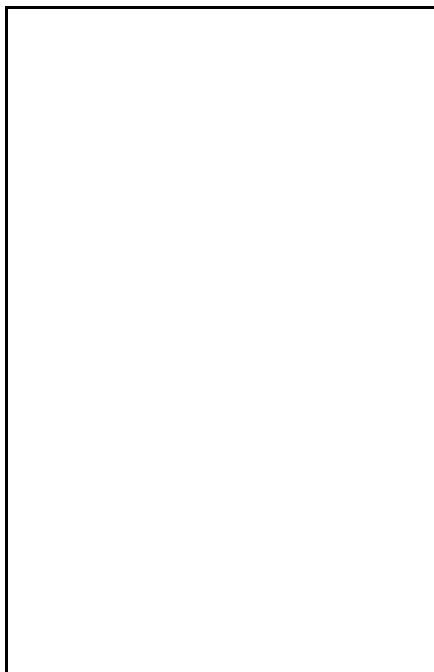
NREL is active in a number of efforts that directly support the emerging roadmap for the chemical industry's research and development needs. One area involves the development of flexible chemical processing to enhance the use of recycled materials in the chemical industry.

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**Research to extract the component sugars (of corn fiber) and upgrade them to valuable chemicals, such as propylene glycol, is the subject of a CRADA with the National Corn Growers Association.**

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Other projects involve: evaluating the production of a valuable component of wood pyrolysis oils for use as an additive to paper to decrease aging and yellowing; isolating and using sugars derived from wastes or other lignocellulosic feedstocks to produce higher-value chemicals such as lactic acid; defining opportunities for enzymes to operate in organic solvents and evaluating their function in these hostile environments; developing simple and powerful computational tools to assist experimentalists in the design of useful proteins; and developing advanced materials for more stable and selective membranes for removing carbon dioxide from natural gas and other applications.



NREL is working with the National Corn Growers Association, the U.S. Department of Agriculture, and others on new technologies and directions to benefit U.S. agriculture, such as using corn fiber for high-value chemical intermediates. (Photo - Warren Gretz, NREL)

As part of establishing an independent agricultural vision, DOE and the U. S. Department of Agriculture have signed a memorandum of understanding that they will cooperate in the development of science, engineering, and technology that will benefit the American agricultural community and meet the mission needs of both departments. The National Corn Growers Association and the Corn Refiners Association are leading the agriculture industry to create a vision of the future. Visioning and roadmapping will occur in FY 1997 and will form the basis for defining research direction and needs.

NREL is also part of a five-laboratory consortium which allows five labs to synergistically work together to further the goals and objectives of the chemical vision and the emerging agriculture vision.

At NREL, three efforts already support the future vision of the agriculture industry. One effort involves the use of alternative feedstocks for the production of chemicals and materials. Corn fiber is a by-product of corn wet milling and is currently used as a low-value animal feed. Research to extract the component sugars and upgrade them to valuable chemicals, such as propylene glycol, is the subject of a CRADA with the National Corn Growers Association. This complements another project involving a CRADA effort with Eastman Chemicals to extract cellulose from woody materials in high yields and purity using novel technologies developed at NREL.

The second effort involves upgrading levulinic acid, a chemical derived from wastepaper sludge, into more valuable chemicals that could serve as fuel oxygenates, green agrichemical pesticides, or intermediates in the manufacture of industrial polymers. NREL has a CRADA in this area with a small business, Biofine, and the New York State Energy Resources Development Authority. Additionally, NREL is designing and developing biocatalysts for use in the chemicals industry that also have application in the agriculture industry.

A third effort involves converting corn syrup biologically into a chemical intermediate, succinic acid, and then chemically converting this intermediate into a range of potential products useful in manufacture of plastics, synthetic polymers, and solvents. This effort involved four of the laboratories involved in the seminal virtual laboratory effort in the DOE Alternative Feedstocks program—Argonne National Laboratory, Idaho National Engineering and Environmental Laboratory, NREL, and Pacific Northwest National Laboratory. This arrangement allowed a small business, Applied CarboChemicals, to access the capabilities at all four laboratories under a multilab CRADA to carry out the pilot-scale demonstration of this technology.

## Forest Products Industry

The forest products industry sector also has had an industry vision, *Agenda 2020*, since November 1994. In this vision, the industry defines six technical areas that will assist this industry in maintaining its competitiveness in the world: sustainable forest management, environmental performance, energy performance, improved capital effectiveness, recycling, and sensors and controls.

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**NREL conducts R&D projects consistent with the needs expressed by industry, currently in the areas of sustainable forestry, environmental performance, and sensors and controls.**

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Industry-led committees have worked out technology roadmaps which define the needed research and technology development. DOE national laboratories, acting as a system of capabilities, have formed working groups in each of the six areas. These committees assist in soliciting input from laboratories, industry, and academia prior to submitting proposals that address industry-defined

needs. Industry makes recommendations about which potential proposals would be suitable and DOE allocates resources based on their programmatic selection criteria. NREL has representation on all six technical area working groups, and co-chairs two of them.

NREL conducts R&D projects consistent with the needs expressed by industry, currently in the areas of sustainable forestry, environmental performance, and sensors and controls. These projects were reviewed by industry teams from many submitted by laboratories and universities, and were recommended for funding to DOE. Other projects are being defined as OIT and the forest products industry move through their recommendation and selection process.

The forest products sector is a vibrant and active area of interest for NREL and is very closely aligned with the core capabilities at NREL. Specific projects include the following: employing sophisticated analytical capabilities to differentiate between plant cultivars; evaluating novel approaches to

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**In addition, the synergism and coordination between the biomass power activities ... and the forest products industry activities ... allows accomplishing the goals with less overall resources.**

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treating waste waters to eliminate contamination by heavy metals and increase the ability that mills can close their water cycle; investigating how to oxidize volatile organic compounds in wastewater streams at low temperatures; investigating, with Ames Laboratory, the development of a simple and powerful method to correlate pulp characteristics with wood chip quality or even standing trees; and investigating, with the Institute for Paper Science and Technology, the production of a low-cost, sulfur-free pulping catalyst derived from lignin for Kraft pulping operations.

In addition, the synergism and coordination between the biomass power activities (see page 1-7) and the forest products industry activities allows researchers from NREL, collaborators from industry, and program managers from the Offices of Utility and Industrial Technologies to accomplish their technological goals with less overall resources.

## **Petroleum Refining Industry**

The Petroleum Refining vision is being developed; included in that vision is an emphasis on developing technologies to deal with the unique environmental issues of the refining industry. NREL has employed its capabilities in solar detoxification to help Solarchem Environmental Systems and a petroleum refiner to demonstrate solar water remediation of organics at an actual refining operation site. Laboratory results at NREL show complete mineralization of organics including chlorinated compounds which are difficult to treat by other methods. A larger scale demonstration at the refinery operation site is the next step.

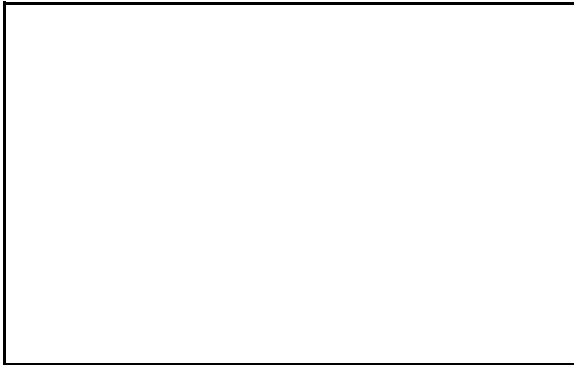
## **Other Industries**

NREL participates in the roadmapping for the visions developed by the glass, metal casting, steel,

and aluminum industries. NREL will become involved as matches are found between technology needs and NREL capabilities.

## ***Cross-Cutting Industrial Technologies***

OIT also recognizes that many technologies cut across industry sectors such as materials development, design and use of more efficient engines and turbines, separation technologies, and others. NREL is involved in advanced materials development for membrane separation of gases that could be applied to chemicals, petroleum refining, forest products, and agriculture.



These pellet fuels made from waste, called refuse-derived fuels, can be burned with coal in a utility or industrial boiler to reduce the amount of waste going to landfills. NREL helps to foster collaboration among several industries jointly addressing their waste management opportunities. (Photo - Philip Shepherd, NREL)

Waste management is another critical cross-cutting element for all industries and is increasingly highlighted in many of the industry visions. Raw material production, product manufacture, and consumption all generate wastes that are resources for new products and energy production. DOE/OIT has been a leader in developing technology for recycling factory waste in several industries. The chemical industry (American Plastics Council) and forest products industry (American Forest and Paper Association) cosponsored with NREL and DOE a symposium on cofiring paper and plastic waste with coal in factory boilers. This productive use of

wastes targets both factory scrap and post-consumer waste.

American industry is predicting their increased responsibility in the waste management area based on what has been happening in Europe. International trends focus on making industry participate in the management of post-consumer waste from manufactured products and especially packaging. New landfill laws in Europe severely restrict the organic content of landfilled wastes; it will soon be impossible to discard waste with an organic content over 5% and, in most cases, 3%.

Industry and communities will have to treat their wastes to make all landfilled material almost completely inorganic. There will be opportunities for industry to collaborate together and with government, applying waste treatment technologies previously used in the public sector for managing household and commercial waste.

**NREL has the experience and knowledge to work with all industries to assist them in developing sound methods and systems for managing factory and post-consumer waste.**

NREL has the experience and knowledge to work with all industries to assist them in developing sound methods and systems for managing factory and post-consumer waste. One key continuing project is the use of anaerobic digestion technology for converting solid waste and tuna sludge into medium Btu gas and compost. This technology is reaching pilot-scale operation with a high potential for commercial implementation in the next 3–5 years. NREL is assisting a new small business formed to pursue the commercialization of this technology.

Considerable experience from industrial projects in prior years is being documented by NREL, and technology information is being provided to assist the industries in using the available knowledge to reach their goals defined in the industry visions. NREL also has demonstrated the skill to foster collaboration among several industries jointly addressing their waste management opportunities. NREL enables industry and municipal waste managers to develop and implement cost-effective, environmentally responsible, and energy-efficient strategies to separate, recycle, and remanufacture from post-consumer waste, and dispose of waste materials.

### ***Technology Access***

NREL researchers provide technical assistance to DOE's Alliance for Industrial Excellence. This alliance includes such programs as National Industrial Competitiveness through Energy, Environment, and Economy (NICE<sup>3</sup>), Climate Wise, and the Industrial Assessment Centers.

NREL participates in the technical review of NICE<sup>3</sup> proposals. With DOE, the Environmental Protection Agency, Small Business Administration, and local organizations, NREL provides technical assistance in Climate Wise, the voluntary partnership program. NREL assists local industries joining this program with its technical knowledge of renewable energy technologies and other areas.